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The coding hypothesis and zero-delay matching-to-sample in the pigeon.

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THE CODING HYPOTHESIS AND ZERO-DELAY MATCHING-TO-SAMPLE IN THE PIGEON

A thesis Presented
by
Robert Alan Sacks

Submitted to the Graduate School of the University of Massachusetts in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE
May, 1971
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THE CODING HYPOTHESIS AND ZERO-DELAY MATCHING-TO-SAMPLE IN THE PIGEON

A Thesis
by
Robert Alan Sacks

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(Chairman of Committee)

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May, 1971
Twelve Carneaux pigeons were divided into three groups and trained on zero-delay matching-to-sample, fixed ratio matching-to-sample or zero-delay non-matching. Reinforcing only every third correct match with grain was found to substantially slow acquisition. Learning matching or non-matching with red and green stimuli did not produce generalized transfer nor did the transfer task interfere with performance on the original problem. Re-pairing the stimuli so as to change the odd comparison stimulus was shown not to affect matching performance but to cause a decrement in non-matching in two out of three cases. Interpolation of a one second delay between the offset of the standard stimulus and the onset of the comparisons caused all animals to drop to chance performance, from which they never improved. The results are interpreted in terms of the coding hypothesis of Cumming et. al. (1965).
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In the matching-to-sample (MTS) situation, the subject is presented a standard stimulus (ST) and then required to respond to the appropriate comparison stimulus (CO) from among a choice of two or more. MTS may be characterized by the temporal or physical relationship between the standard and comparison stimuli. If the COs are shown in the presence of the ST, the procedure is termed simultaneous matching. Zero-delay matching is the case in which a response to the standard results in the immediate removal of the ST and presentation of the choice stimuli. The choice response is therefore made in the absence of the standard. The logical extension of the zero-delay procedure is the interpolation of a time interval between ST offset and onset of the COs. This is termed delayed matching-to-sample (DMTS). Matching has been described as a particularly good situation for studies of delayed responding, since the problem cannot be solved by spatial orientation alone (Berryman, Cumming and Nevin, 1963).

It is also possible to manipulate the physical relationship between ST and COs. In the matching paradigm the subject is typically required to pick a CO which is physically identical to the ST. If, however, correct solution demands picking the CO which is different from the standard, the procedure is called non-matching or oddity. The oddity paradigm has generated a small literature of its own (e.g., Warren, 1960; Boyd and Warren, 1957; Pastore, 1955; Ginsburg, 1957; Berryman, Cumming, Cohen and Johnson, 1955). A further variant of the matching procedure is amatching, in which the standard and comparison stimuli are
physically different and a correct "match" is predetermined by the experimenter. For example, the subject may be required to pick the yellow CO when presented a red ST and a blue CO when given a green ST. This differs from non-matching in that the correct CO need not be the "odd" one and the relationship between a particular ST and CO is defined and constant within a problem.

While there have been only a few theoretical analyses of matching-to-sample, many psychologists have used the technique as a convenient means to other ends. Hively (1962), for example, has used the paradigm in a Skinnerian teaching machine with young children. Rohles (1961) included matching in an instrumental skill sequence in an effort to measure "higher cognitive functioning" in chimpanzees during space flight. Spaet and Harlow (1943) successfully trained rhesus monkeys to respond to delayed response problems using this technique after bilateral removal of the prefrontal areas. Weinstein (1941) concluded that the method was well suited for comparative studies of adaptive behavior in monkeys and preverbal children and predicted that it would be used in the investigation of "the neurophysiological correlates of higher mental processes."

The first systematic theoretical account of MTS was that of Nissen, Blum and Blum (1948). They first trained chimps to match cups and boxes using a modified correction procedure (a problem was repeatedly presented until correctly solved). Mastery of this task to a criterion of ten successive correct responses required from 177-547 trials (correction trials were not included). Successful transfer was demonstrated to 77 new object combinations.
The study itself is, by contemporary standards, methodologically weak. The age of the chimps ranged from 5 to 23 years, animals were permitted to respond to either the sample or the comparison stimuli in any order, and previous experience varied from naive to specific matching training. Despite the obvious lack of controls, the fact that matching was acquired and did transfer to novel stimuli is undeniable. In an attempt to explain their results, Nissen et al. offered three ways in which similarity or difference between sample and choice objects may be effective in producing generalized matching. The first of these is a "learning mechanism" which assumes that the sample objects provide reinforcement of specific visual characteristics on each trial. In other words, the sample becomes a secondary reinforcer and the animal learns to respond on the next trial to the choice object which has the same visual characteristics as the sample. Each problem would then require an independent learning of this kind. The second is a "perception mechanism" which assumes that the subject perceives likeness (homogeneity) or difference (heterogeneity) between the stimulus objects. The subject learns either to approach the large homogeneous area (sample plus correct choice) and to avoid the small area (non-matching choice object) or to approach the small area (correct choice object) and to avoid the large heterogeneous area (sample plus non-matching object), depending on how he divides the visual field.

The third mechanism is "abstract generalization" which assumes that the abstract relationships of likeness or difference may function as cues evoking approach and avoidance respectively.
Nissen et al. claim that all three mechanisms are probably effective either separately or in combination.

Skinner (1950) trained pigeons to match using two-dimensional colored keys. With two colors and three keys it is possible that the bird could learn to respond differentially to the four three-key patterns (i.e., XXY, XYY, YXX, YYX). Skinner states that this is not the case, however, since if a series of settings of the colors is presented without requiring an observing response to the ST, the pigeons will strike the side keys without respect to color or pattern and be reinforced 50 percent of the time. That is, in effect, a partial schedule and is sufficient to maintain a high rate of responding.

Eckerman, Lanson and Cumming (1968) discuss a "unitary stimulus" analysis of MTS which is closely related to both Skinner's idea of differential responding to three-key patterns, and the perception mechanism of Nissen et al. Given the small population of stimuli used and a three-key display, it is possible that the whole display might be acting as a unitary stimulus controlling "respond left" or "respond right." When the keys are fairly close together MTS training may simply strengthen the response to the "larger" color (Nissen et al.'s homogeneity). Smith (1967) successfully trained delayed matching with a stimulus display where the ST was on the front wall of the chamber and the COs were on the side walls. In addition, his stimuli were a vertical or horizontal line, perhaps making a large homogeneous area harder to abstract from the display. Eckerman et al. point out that the unitary stimulus analysis
cannot explain matching acquisition if it is shown that accurate performance is dependent upon a separate observing response to the ST. They demonstrated that matching is facilitated by a procedure which requires a response to the standard. There was also some indication that, in a bird well trained in zero-delay matching, introduction of a cancel procedure (responses to ST extinguished all lights for 25 seconds) produced an overt observing response (pecking in the area of the ST). They predicted that continued exposure to the cancel procedure would promote the development of some non-keypeck observing response to the ST. It is clear that an observing response, or at least temporal sequencing of the ST and COs, facilitates both speed and accuracy of MTS acquisition. This raises some problems for the perception mechanism, at least in pigeons. Eckerman et. al. have also convincingly devastated their "unitary stimulus" straw man. Weinstein (1941) also rejected what he called a "maximal area" theory in primates. With matching experienced monkeys and pre-verbal children he used a simultaneous MTS procedure with four choice objects. The three negative COs were identical, making the maximal area of stimulus objects negative. All the subjects solved this task with no apparent hesitation or decrease in accuracy.

It would seem that both the "perception mechanism" and unitary stimulus explanations are inadequate. It is possible that some kind of conceptual learning could take place. This could be in the form of Nissen et. al.'s "abstract generalization." One feels compelled to invoke Morgan's Canon here and resort to abstract
generalization only if all else fails. One could conceivably make a case for such a process in non-human primates, but extending it to pigeons seems presumptuous at this point.

However, a learning mechanism is possible. A process similar to the development of a learning set could be effective in producing transfer of matching. Learning set acquisition is well established in a variety of primates and there are indications that a learning set can be acquired by pigeons (Ziegler, 1961) and crows, mynahs and bluejays (Kamil and Hunter, 1970a,b). There is, however, an important difference between a learning set procedure and that of MTS. The development of learning set requires many novel stimuli presented for a few trials each. By contrast, in MTS a criterion performance with one set of stimuli is required before transfer to novel stimuli. In matching, the total stimulus population may consist of four or five colors or objects whereas in learning set there may be hundreds. There are indications that squirrel monkeys trained on a single discrimination problem for many trials do not show the same kind of transfer to learning set as those given an equal number of presentations of six trial problems of conventional learning set (Ricciardi and Treichler, 1970). It is therefore not unreasonable to assume that the animal learns something quite different in the two situations.

Cumming, Berryman and Cohen (1965) and Berryman et al. (1965) have offered a mediational model of stimulus control in zero-delay matching. Their "coding hypothesis" is based on the assumption that responses to the COs are mediated by some coding response
rather than being exclusively determined by the properties of the ST. This model may also be applied to the case of simultaneous matching, the authors claim, since there is some evidence (Berryman, Cumming and Nevin, 1963) that birds trained on simultaneous MTS show positive transfer to delays of 1 and 2 seconds. It should be noted, however, that the birds in the 1963 study were exposed to delay training during acquisition and thus the application of coding to the case of simultaneous MTS may be premature.

The coding hypothesis states:

"... § learns to make an appropriate coding response \( r_x \) in the presence of a particular standard stimulus \( \text{ST}_x \). In the presence of \( r_x \), the two comparison stimuli \( \text{CO}_x \) and \( \text{CO}_y \) are presented. The chain \( \text{ST}_x -- r_x / \text{CO}_x -- R_x \) is reinforced, while \( \text{ST}_x -- r_x / \text{CO}_y -- R_y \) is extinguished (in which \( r_x / \text{CO}_x \), for example, denotes the simultaneous presence of the coding response to \( \text{ST}_x \) and a particular comparison, \( \text{CO}_x \)). Within the same situation coding responses to \( \text{ST}_y \) are also being acquired, with \( \text{ST}_y -- r_y / \text{CO}_y -- R_y \) reinforced, and \( \text{ST}_y -- r_y / \text{CO}_x -- R_x \) extinguished." (Cumming et al., 1965, p. 437)

The present author feels that the coding hypothesis has the widest potential generality of the theories of MTS yet proposed. Skinner (1950) recognized the desirability of reinforcing the discriminative response of "striking-red-after-being-stimulated-by-red" and hitting "green-after-being-stimulated-by-green," while extinguishing the other two possibilities. Although Skinner provided no mechanism, this seems to be an early form of the coding hypothesis.

Cumming and Berryman (1961) trained pigeons in simultaneous MTS using red, green and blue stimuli. For two sessions (after matching was well established) a yellow light was substituted
for blue on both the center and side keys. The ability to match red and green was unimpaired but the birds reverted to position preference whenever the ST was yellow. They conclude that training to match red, green and blue stimuli had not resulted in the formation of a "matching concept" applicable to novel stimuli. This position preference during a yellow ST disappeared faster than the original position habit, implying that some transfer of learning occurred. Clearly, the animal learned neither a matching concept nor that the odd hue was to be avoided, otherwise performance would have been above chance when the ST was yellow.

Blough (1959) trained four pigeons in delayed MTS and observed repeated, stereotyped response chains during the delay interval between ST offset and onset of the COs. It should be noted that Blough did not require a response to the ST, which consisted of either a flickering or steady light. In two of the birds this chain was of two distinct topographically different forms, each form corresponding to one condition of the sample stimulus. The other two birds had been given more extensive exposure to the zero-delay training procedure and were significantly poorer in delay performance. Blough claims that "to the extent that the superstitious chains were correlated with the sample stimuli, they themselves provided discriminative stimuli for the matching responses" (p. 157).

Although the present author is reluctant to limit the coding mechanism to overt motor activity, it is felt that the coding hypothesis offers the most viable explanation of MTS. The present study is an attempt to gather more data on matching in the pigeon
and to provide a test of several aspects of the coding hypothesis, by examining interference, transfer and retention phenomena. There are several aspects of the code which can be tested. If, as Cumming et al. (1965) imply, the code is specific to each stimulus, one would expect that there should be little transfer to novel hues. If the codes are specific, they may well be independent. If so, coding a few new stimuli should not interfere with those codes already established. Finally, re-pairing stimuli to which codes have already been attached and delaying the onset of the comparison stimuli may yield information about the physical and temporal nature of the coding mechanism.
METHOD

Subjects

Subjects were 12 Palmetto White Carneaux pigeons maintained at 80-85% of free feeding weight. Water was continuously available in the home cages. The reinforcement mixture consisted of Purina Pigeon Grains. The animals were weighed daily and the same mixture was given in the home cage when feeding outside the experimental situation was required.

Apparatus

The operant chamber was constructed of masonite and plexiglass (34 X 34 X 32 cm.) and was enclosed in a plywood sound attenuating chamber lined with styrofoam. White noise was provided via a speaker mounted on the rear wall of the inner chamber. Three Lehigh Valley pigeon keys were mounted on one end wall at a height of 21 cm. and spaced evenly 8 cm. apart. The food magazine was mounted approximately 10 cm. below the center key. A light inside the grain hopper was illuminated whenever the feeder was operated. Ventilation was provided by a fan on the outside of the plywood enclosure. A small 28V houselight was mounted on the top of the operant chamber and arranged so that it would not shine directly on the keys. Stimulus presentation was via IEE projectors mounted directly behind the keys. Programming was by paper tape reader and relays located in an adjacent room.

Procedure

Preliminary training. Each pigeon was given 2-3 days of habituation to the operant chamber prior to magazine training, during which the house light and white noise were on but neither
the key lights nor the feeder were operative. The birds were
magazine trained by presenting the grain hopper for 5 seconds
on a VI-1 minute schedule. Any bird which had not begun to eat
from the hopper after a second daily one hour session was given
a longer (10 sec. or more) presentation. After magazine training,
each bird was shaped to press one of the side keys, which was
illuminated with white light (initial side was counterbalanced in
each group). Each press of a lit key was rewarded with 3 second
access to grain. The birds were then given an approximately equal
number of reinforcements on each of the three keys, only one being
illuminated (white only) at any one time. The subjects were
divided into groups of 4 and randomly assigned to the three
experimental conditions.

**General procedure.** The basic procedure for the three groups
was as follows. The birds were first placed on red-green (R-G)
zero-delay matching. With three keys and two colors there are
four possible stimulus configurations (RRG, RGG, GGR, GRR). Each
possible configuration was represented an equal number of times
within a session. A response to the center key resulted in the
removal of the ST and presentation of the COs. The first
response to either CO extinguished the side keys and initiated
either reward or timeout (TO). Correct choice responses were
rewarded with three second access to grain while incorrect responses
were followed by a ten second timeout in which all lights in the
box were turned off. A new trial (presentation of ST) was initi-
ated automatically after either the offset of the feeder or the
termination of the TO. The birds were run for daily 80-trial
sessions which continued until criterion (90% correct or better on three consecutive days) was reached.

As each subject met criterion on R-G matching, the bird was transferred to blue-yellow matching (B-Y). Just as in the previous step, the patterns were BBY, BYY, YBB, and YYB. All other contingencies remained the same. This transfer task was run to the same criterion as R-G. Each bird was then retested on R-G to determine the degree of interference of the B-Y transfer task on original R-G acquisition. Again, a criterion performance was required before proceeding to the next stage.

The 4th phase consisted of a reorganization of the four colors into R-B and G-Y pairs. Each of the eight resulting stimulus configurations (RRB, RBB, BBR, BRR, GGY, GYY, YGG, YYG) was equally likely to appear within an 80 trial session. The birds were again run to criterion. The rationale for this stage was twofold. First, since it is unlikely that a bird could respond to eight new patterns differentially, another test of the "unitary stimulus" hypothesis was provided. Secondly, the re-pairing resulted only in the substitution of a previously unpaired color within each configuration as the odd stimulus. Although the colors were re-paired, none of the colors were novel to the animal and thus it was hoped that generalization decrement effects would be minimized.

Several birds in each group were then exposed to a delay procedure after they had completed all phases of their respective tasks. As the last task in each case was the R-B, G-Y re-pairing, it was upon this phase that the delay was imposed. A one second interval between the offset of the ST and onset of the COs was
instituted. As before, a response to the ST was required, reward was three second access to grain and incorrect choice responses were followed by a ten-second TO.

**Group 1: MTS-CRF**

Four birds (P1, P2, P3, P4) were assigned to Group 1. The procedure for this group was exactly as outlined above. P1, P3 and P4 were given 1600, 2640 and 1600 delayed matching trials respectively.

**Group 2: MTS-FR**

Four pigeons (P5, P6, P7, P8) were given fixed ratio matching. The procedure was as above with the exception that the birds were reinforced with grain only for every third correct match. Each correct match was reinforced with a three second presentation of the feeder light and all incorrect matches were followed by a ten-second TO. The three correct matches did not have to be consecutive. The birds were given 240 trials per day in 80 trial segments and criterion was defined as three consecutive 80 trial segments at 90% correct or better. P5 and P7 were given 1920 and 1600 respective FR-3 delayed matching trials.

**Group 3: Non-Matching (NMTS)**

Four naive birds (P9, P10, P11, P12) were exposed to the non-matching procedure. The same stimulus tapes as in the two previous groups were used. Most of the contingencies of the general procedure also applied, with the exception that the apparatus was rewired such that the bird was reinforced for picking the non-matching or odd CO. It should be noted that this method differs from conventional oddity in that only two colors were used in each
phase. Birds were run 80 trials per session, were reinforced with grain for each correct response and received a ten-second TO for each incorrect choice. P9 (1200 trials) and P12 (960 trials) were given delayed non-matching.
Group 2: Fixed Ratio Matching

This group was run to answer a methodological question. It was hoped that by reinforcing only every third correct match, three times as many trials could be run in each daily session without satiating the birds. Thus, it was hoped that acquisition could be shortened (in terms of days) and future studies run more efficiently.

The results, presented in Table 1, show that the attempt was a disaster. Two of the four birds were dropped. In the case of P8 more than 10,000 trials were required for R-G acquisition, while P6 never learned B-Y (after 10,000 trials).

There was great variability in the performance of all subjects. The percentage correct fluctuated considerably from day to day for each subject. A clear upward trend confirms the fact that matching was acquired but the variability continued at each level of performance, thus making the requirement of three consecutive segments at 90 percent or better especially difficult.

Group 1: CRF Matching

The results for group 1 are shown in Figure 1. Individual records for each bird are presented since, although clear trends
emerge, there was considerable between-subjects variability. Acquisition of R-G MTS required from 22-35 sessions. In all cases there is a period of chance or near-chance responding early in acquisition. Three of the birds exhibited strong color preferences in this period, while the responding of the fourth (P4) was dominated by position preference.

B-Y acquisition generally required fewer sessions than R-G, but the slopes and shapes of the two curves are similar (strikingly so in the case of P3). There is a consistent shortening of the flat, chance-responding early period in every case. These two facts suggest that the transfer which did occur resulted only from a general familiarity with the apparatus and situation. Strong color preferences during B-Y acquisition were generally only of short duration. There was little saving from R-G to B-Y in terms of trials to criterion (Fig. 3), although the birds tended to make fewer errors in B-Y (Fig. 4).

B-Y acquisition seems to have interfered with R-G performance in only one of the four cases (P2). Whatever it is that the birds learned seems to be specific to the stimuli and largely unaffected by relearning matching with other hues. The possibility of a "concept formation" explanation seems reduced. This, however, does not rule out the possibility of a unitary stimulus explanation. It is probable that the learning of the two matching tasks was independent, although a similar "strategy" may have been used for each.

When switched to the 8 configurations of the re-paired R-B, G-Y stimuli, however, 3 birds showed immediate transfer and in
no case was initial performance less than about 70%. The data of P2, which is consistently more variable than that of the other three birds, still shows clear transfer in the R-B, G-Y task. It should be noted at this point that P2 ran at a more uneven rate than the other birds, sometimes requiring more than twice the average time to complete an 80 trial session. This bird was so clearly different from the others in temperament and ease of handling that the variability in its data is distressing but not surprising.

These results are consistent with only two theoretical viewpoints thus far published. These are the perception mechanism of Nissen et. al. and the coding hypothesis. The idea of concept formation in the pigeon has already been dismissed as nonparsimonious and the perception mechanism has been devastated elsewhere. The perception mechanism is also unlikely to be effective in zero-delay matching since the ST is never presented with the COs, and if it were used, should have produced more transfer from R-G to B-Y in contrast to the parallel curves obtained in Figure 1.

The coding hypothesis, as interpreted by the present author, would predict that the pigeons would be reinforced for and learn ST_red→r_red/CO_red→R_red and ST_green→r_green/CO_green→R_green during R-G acquisition. There is no reason to predict that the learning of ST_blue→r_blue/CO_blue→R_blue and ST_yel.→r_yel.→CO_yel.→R_yel. would interfere with previous learning, since all four codes are specific to stimuli which do not overlap. The R-B, G-Y re-pairing merely changed the color of the incorrect CO, which should not affect the nature or effectiveness of the already established
codes. Some small interference might be expected due to the novelty of the situation, which is reflected in the initial 75-80% performance on the first day or two of R-B, G-Y testing. This is followed in every case by a rapid rise to criterion, marred only by the variability of P2.

**Group 3: Non-Matching (NMTS)**

The individual records for the four pigeons run in group three are presented in Figure 2.

---

**Figure 2 about here**

---

In R-G non-matching the subject is presented with the four stimulus configurations, RRG*, R*GG, GGR*, G*RR (the asterisk denotes the reinforced CO). The possibilities for coding are:

\[
\begin{align*}
S_{\text{red}} - &- r_{\text{red}} / C_{\text{red}} - - R_{\text{red}} \\
S_{\text{green}} - &- r_{\text{green}} / C_{\text{green}} - - R_{\text{green}} \\
S_{\text{red}} - &- r_{\text{red}} / C_{\text{green}} - - R_{\text{green}} \\
S_{\text{green}} - &- r_{\text{green}} / C_{\text{red}} - - R_{\text{red}}
\end{align*}
\]

The theory predicts that all four of these possibilities occur in acquisition. In matching, the first two are reinforced while the second two are extinguished. In non-matching the situation is exactly the opposite.

As in the case of matching this analysis predicts little transfer to new colors. Even more clearly than in the matching data, the lack of transfer to B-Y is evident. This is shown in terms of percentage correct (Figure 2) and trials and errors to criterion (Figures 3 and 4). One bird (P11) never achieved
consistent performance above 70 percent in B-Y and was dropped from the study. Pll required 59 sessions for R-G acquisition (40 of which are shown in Figure 2). The variability in his data is immediately apparent. This particular bird was also the only subject to form a strong position preference during original (R-G) acquisition. Pll reacted almost violently to being handled and would have been eliminated at the start had a replacement been available.

The assertion that the learning of B-Y is independent of and does not interfere with original R-G non-matching is strengthened by the fact that when retested on R-G all birds showed immediate criterion performance. This seems to indicate that each ST is coded independently. These conclusions are supported by the plots of errors and trials to criterion (Figures 3 and 4). Interestingly, these two plots show that non-matching subjects had less trouble returning to R-G after learning B-Y than did matching birds. This difference appeared consistently although there is no immediately obvious explanation.

The performance of the individual birds on the R-B, G-Y task reveals that the situation is somewhat more complex. The explanation thus far presented predicts that the birds should show little transfer to the re-paired stimuli. A bird which has learned ST\text{red}--\text{red}/\text{CO green}--\text{R green} could not apply this same code now that red is paired with blue. The bird must relearn
ST_{red} \rightarrow r_{red} / CO_{blue} \rightarrow R_{blue} \) and likewise for the four colors.

Figure 2 shows that there seem to be two cases in the R-B, G-Y transfer task. P9 transferred with no apparent difficulty while P12 shows little evidence of transfer and the data of P10 may be suggestive of negative transfer. Even though P10 and P12 showed little or no transfer in terms of percentage correct or trials and errors to criterion, the initial level of performance is quite high for these two birds.

Two strategies consistent with the coding hypothesis are possible in the acquisition of non-matching. The bird can learn a code which signals avoidance (ST_{x} \rightarrow r_{x} / CO_{x} \rightarrow R_{avoid x}) or one which leads to approach (ST_{x} \rightarrow r_{x} / CO_{y} \rightarrow R_{y}). Both of these would be reinforced in this task and it is not unlikely that both are acquired to some extent. There is no apparent reason to predict that the acquisition functions would differ under either code, but a difference will appear when the bird is exposed to the R-B, G-Y phase.

The choice responses of P9 were evidently mediated almost exclusively by an S^- (avoidance) rule. This "avoidance chain" should not be disrupted by the nature of the avoided CO. Accordingly, for example, after learning to avoid red when it was paired with green, P9 had no trouble continuing to avoid it when it was paired with blue.

The other two birds (P10 and P12) were responding largely in accordance with the S^+ (approach) rule, but were at least occasionally reinforced for avoidance during the course of acquisition. When transferred to R-B, G-Y the S^+ rule no longer
led to reinforcement and hence performance on this task would be impeded. However, the animals did not return to chance responding since occasional use of the already learned S⁻ rule would lead to correct "non-matches."

Delay

All birds when given the 1-second delay procedure immediately dropped to chance performance and showed no significant consistent improvement over the numbers of trials given in each case. Every bird exhibited some degree of position preference, while color preference appeared less frequently.

These data are consistent with those reported by Blough (1959) who found suggestions of an inverse relationship between delay performance and amount of zero-delay pretraining. A bird with no experience with delay and considerable zero-delay pretraining shows no transfer to delay while Blough's data suggest that less exposure to zero-delay would produce greater delay transfer.

Although a careful parametric study is needed to explore the full implications of this finding to the coding hypothesis, the following explanation is offered.

It is possible that the bird learns a code in zero-delay matching which is specific both in its components and duration. If this code is formed in manner analogous to that of other operant chains, it is likely to be fairly long when it first appears. This could explain the ability of a bird to tolerate a delay after short exposure to zero-delay. Carrying the analogy further, the extraneous components would drop out later in training and the most efficient string of events for the
Immediate task would be preserved, a phenomenon familiar to anyone who has ever shaped a pigeon to key peck. If this code is temporally shorter than the delay interval to which the bird is transferred, performance would be poor and slow to improve. A careful examination of the change, if any, in response latency for ST onset to choice response is needed to provide evidence for this contention. One prediction from this explanation is that there should be an optimal period during acquisition for each bird where the pigeon is familiar with the contingencies for reward but not yet so efficient that the code is very short. In this case the use of a stiff criterion in acquisition in terms of percentage correct may be counter-productive, at least in maximizing delay performance.
<table>
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<td>NR</td>
<td>NR</td>
</tr>
</tbody>
</table>
Figure 1: Percentage correct for group 1 (Matching)
Figure 2: Percentage correct for group 3 (Non-matching)
Figure 3: Trials to criterion for groups 1 and 3
Figure 4: Errors to criterion for groups 1 and 3
REFERENCES


